Environment Canada Environnement Canada

Canada

Improved cloud height retrieval for AIRS/IASI assimilation and model validation

Louis Garand, Ovidiu Pancrati, Sylvain Heilliette

Environment Canada

NASA Sounder Science Team Meeting

13-16 October 2009, Greenbelt MD

Research goals

- From real and simulated AIRS radiances, review the cloud parameter retrieval (CO2-slicing) in order to:
  - better understand strengths/limitations
  - improve quality control of AIRS/IASI radiances
  - provide objective means to validate model cloud height/amount distributions

Basic tool: cloud parameters from 4 sources, all at AIRS obs locations:
- directly from model output
- from simulated AIRS, apply CO2-slicing
- from real AIRS apply CO2-slicing
- lidar CALIPSO height observations

Applying same retrieval technique to both real and simulated
Data eliminates ambiguity of definitions between obs/model

CO_2-slicing – minimum residual methods

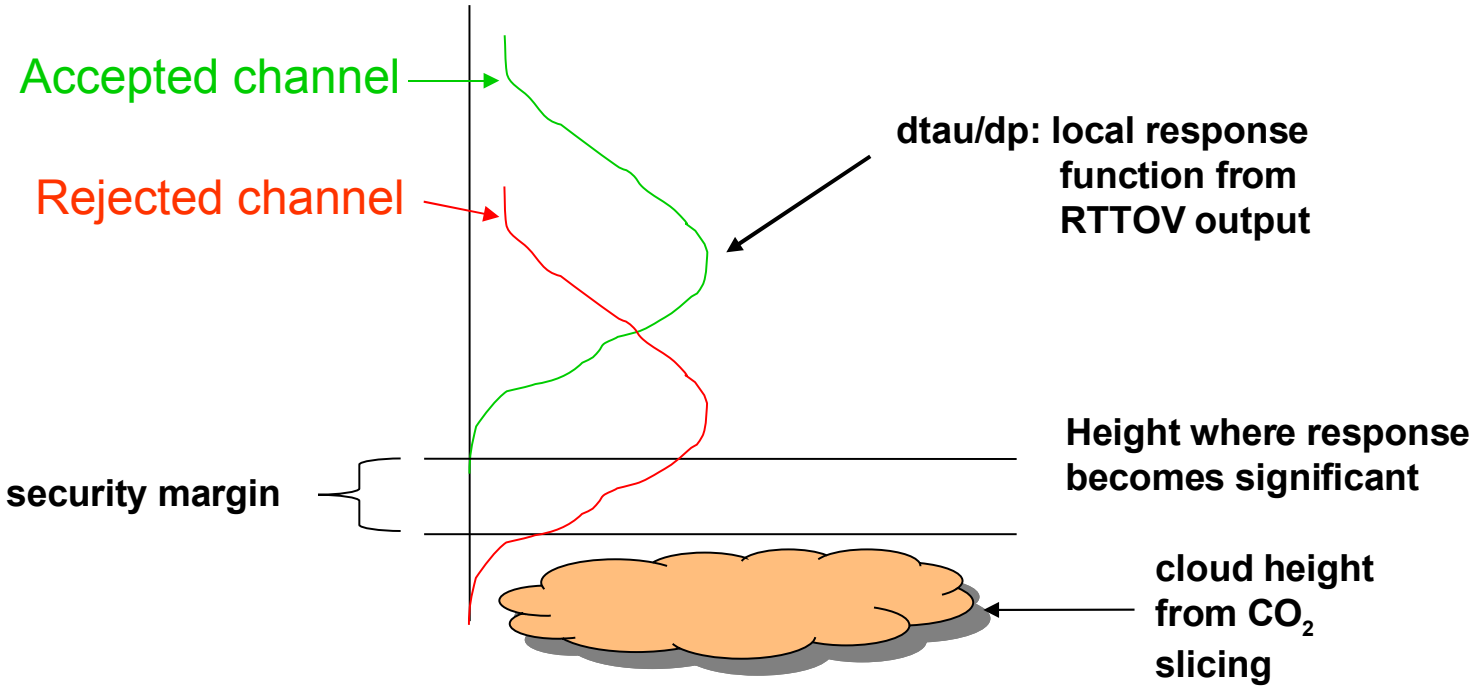
- Dates back to 80s (Menzell et al 1983, Eyre and Menzell, 1989)
- Still the only methods to retrieve equivalent cloud height and amount from single IR FOVs
- Based on radiance ratio of 2 channels, assuming same cloud emissivity, solves for effective height and amount

Issues:

- Channel pair selection
- Assumption on emissivity ratio unity
- Identification of reliable results

Selection of channels not affected by clouds for assimilation

- IASI assimilation setup inspired from AIRS assimilation setup (assimilated operationally at CMC since June 2008)
- Assimilation of cloud unaffected radiances:



Revision of CO2-slicing to get cloud height and amount

following this study

- 13 radiance pairs used, all in range 13.2-14.1 μm
- Median value of height retained with corresponding effective amount

before

- Original implementation for AIRS in 2004 used 12 pairs with channel 528 (12.2 μm) used in all pairs. Mean retained.

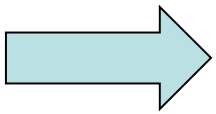
elsewhere

- Several centers use a window channel like 787 (10.9 μm) as reference channel.

Use a 11 micron reference channel paired with a CO_2 channel 12.5-14 micron?

- Advantages
  - 11 micron channel sees all clouds
  - May improve detection of low clouds

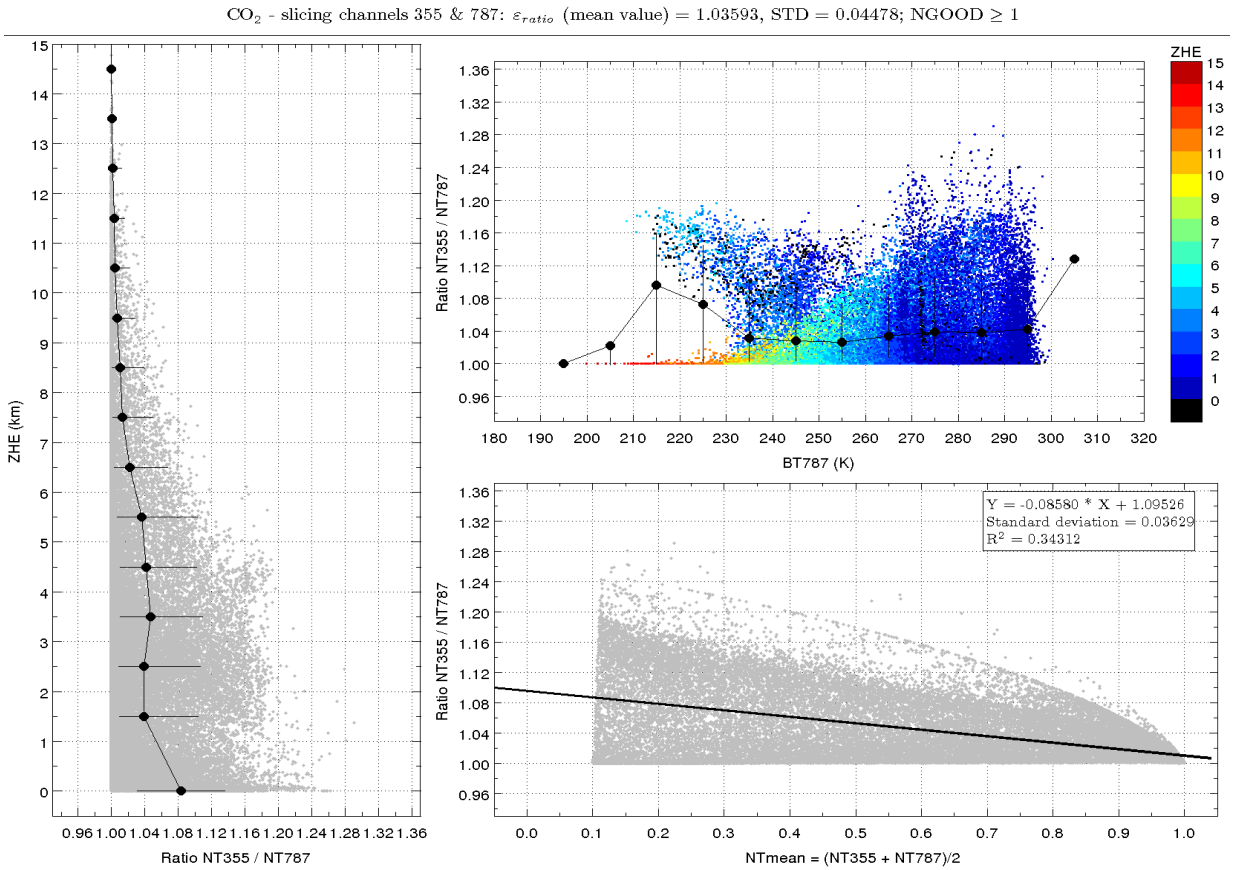
- Disadvantages
  - cloud emissivity ratio not unity: could it be modeled?
  - channel pairs are not independent
  - subject to surface temperature errors more so than using a channel peaking at ~1 km



Recent availability of cloudy RTM allows to study the issue

Cloud emissivity ratio can be far from unity
Ex: 13.3/10.9 micron ratio reaches 1.2

11 mm height vs ratio



Ratio vs 11 µm BT(787)

ratio vs equivalent Cloud amount Ne

Simulated AIRS cloudy radiances

- Uses RTTOV-CLD. Model state from global (35 km) model interpolated at obs location, 6-h or 12h fcsts.
- AIRS center FOV (in assimilation warmest, but this is not suitable for climatology of clouds parameters)

- Definitions of effective model parameters

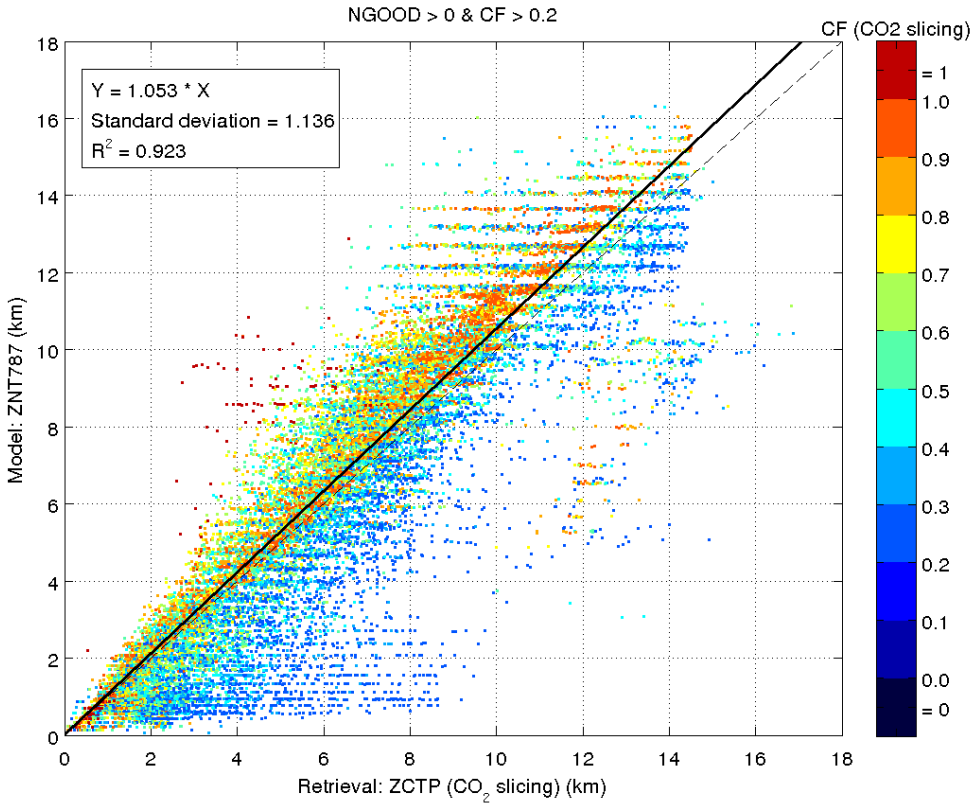
  - height: corresponds to model height where 11 micron cloud transmittance from TOA reaches 0.9

  - amount: 1 – total cloud transmittance, set to zero if < 0.1

Impact of channel pair selection. Model output (true) height versus retrieved from simulated radiances

Configuration with 12 channels coupled to a reference profile peaking near the surface	
Channel #	Wavenumber
204	707.770
221	712.661
232	715.862
252	721.758
262	724.742
272	727.752
299	735.298
305	737.152
310	738.704
355	752.970
362	755.237
475	801.001
Reference channel	
787	917.209

Assuming emissivity ratio = 1.0
Std excluding outsiders: 1.14 km

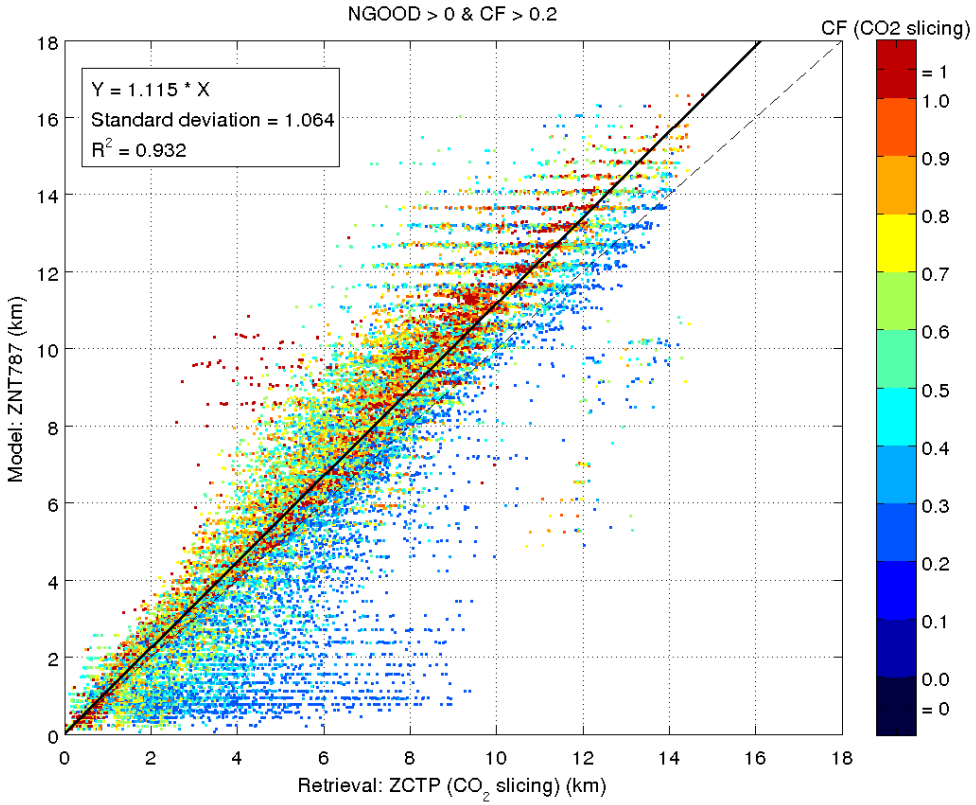


Emissivity ratio considerations

Initial configuration: 12 channels coupled with a reference profile peaking near the surface	
Channel #	Wavenumber
204	707.770
221	712.661
232	715.862
252	721.758
262	724.742
272	727.752
299	735.298
305	737.152
310	738.704
355	752.970
362	755.237
475	801.001
Reference channel	
787	917.209

Emissivity ratio fitted to Ne found in first iteration of Co2-slicing

Std excluding outsiders: 1.06 km

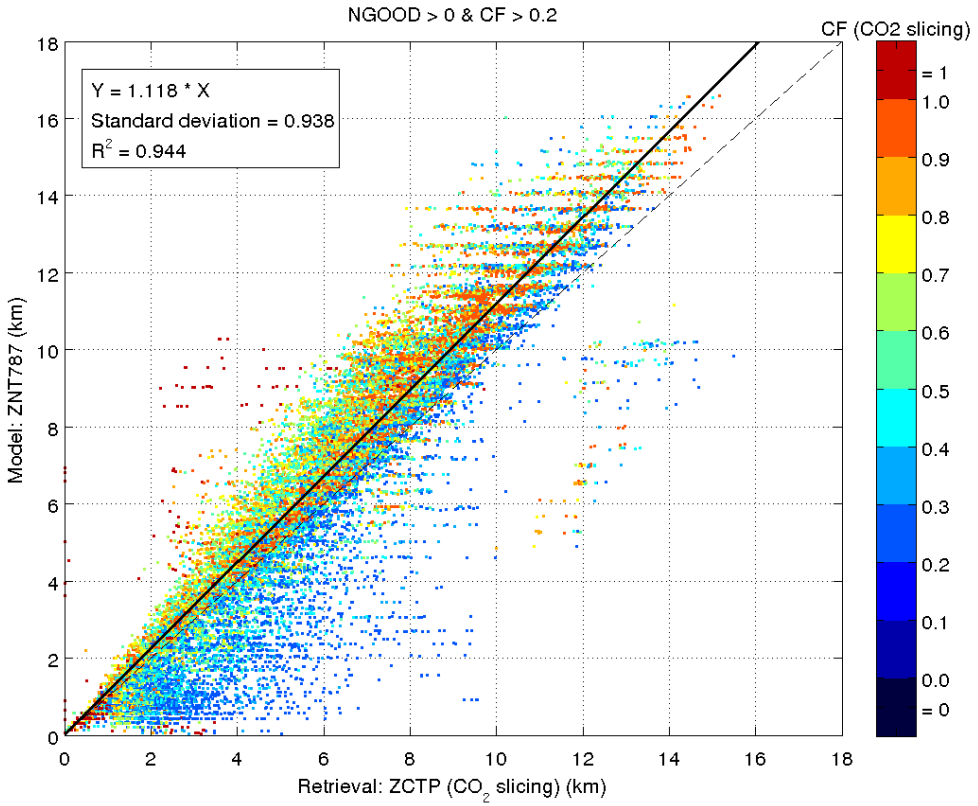


Cloud emissivity ratio considerations

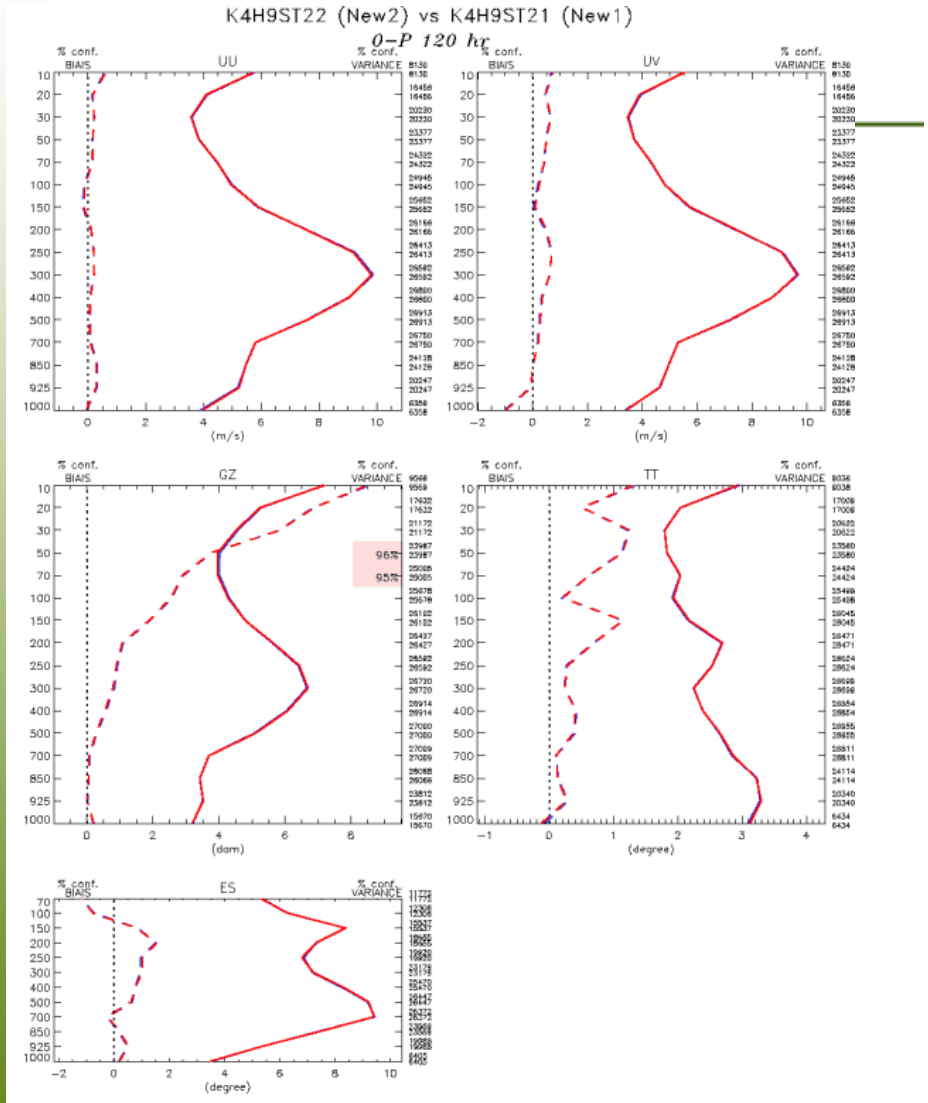
Chosen configuration: 13 pairs of coupled channels In narrow limited range				
	Channel		Reference channel	
Pair #	#	cm^{-1}	#	cm^{-1}
1	**204**	707.770	**252**	721.758
2	**221**	712.661	**262**	724.742
3	**232**	715.862	**272**	727.752
4	**252**	721.758	**299**	735.298
5	**262**	724.742	**305**	737.152
6	**272**	727.752	**310**	738.704
7	**299**	735.298	**355**	752.970
8	**305**	737.152	**362**	755.237
9	**310**	738.704	**375**	759.485
10	**355**	752.970	**375**	759.485
11	**362**	755.237	**262**	724.742
12	**375**	759.485	**252**	721.758
13	**375**	759.485	**204**	707.770

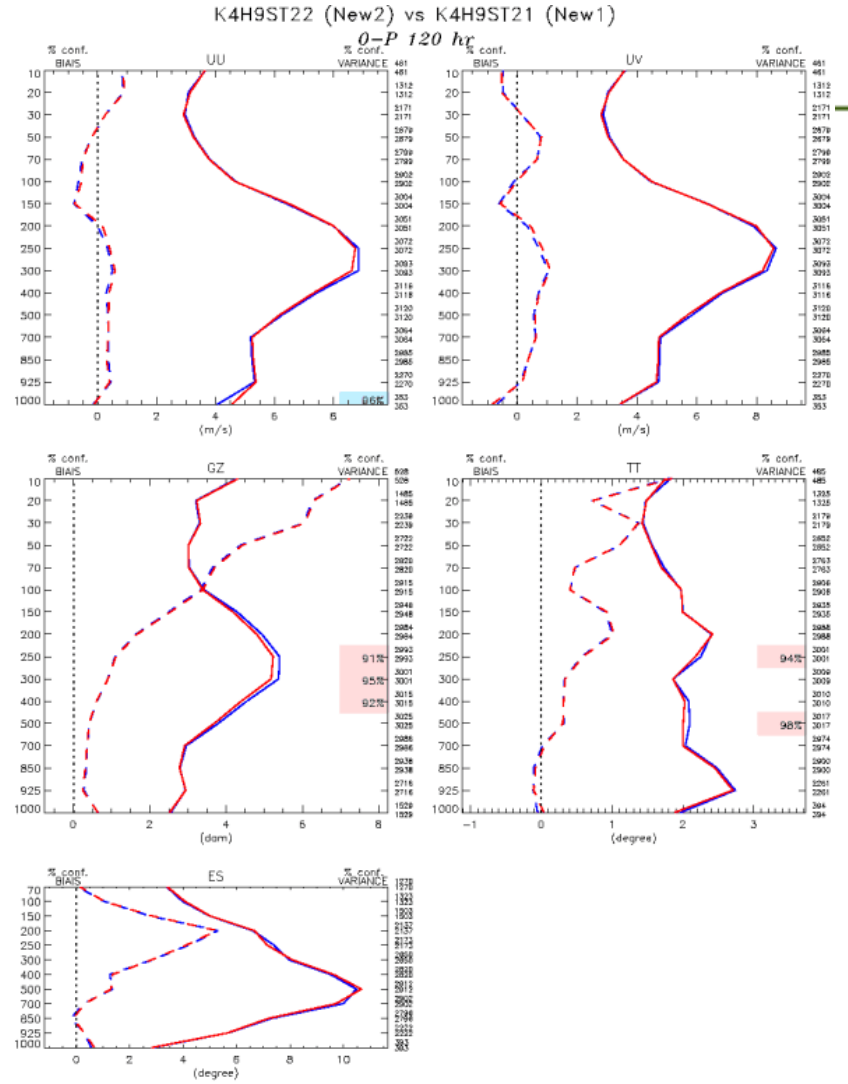
All pairs in range 707-760 cm-1

Std excluding outsiders: 0.94 km



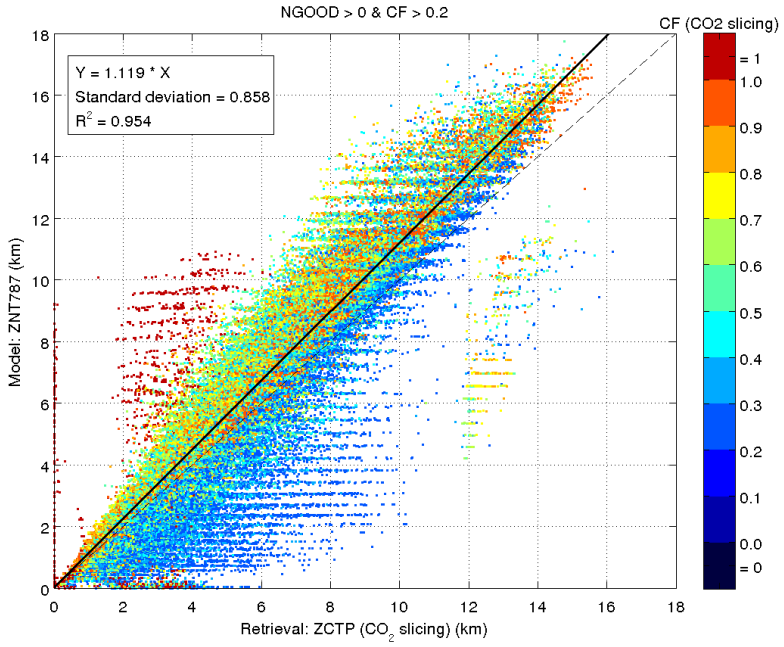
Impact: Ref channel AIRS-528 (820 cm-1), mean of 13 pairs vs all pairs in range 797-760 cm-1, median height of 13 pairs, 120h forecasts vs raobs

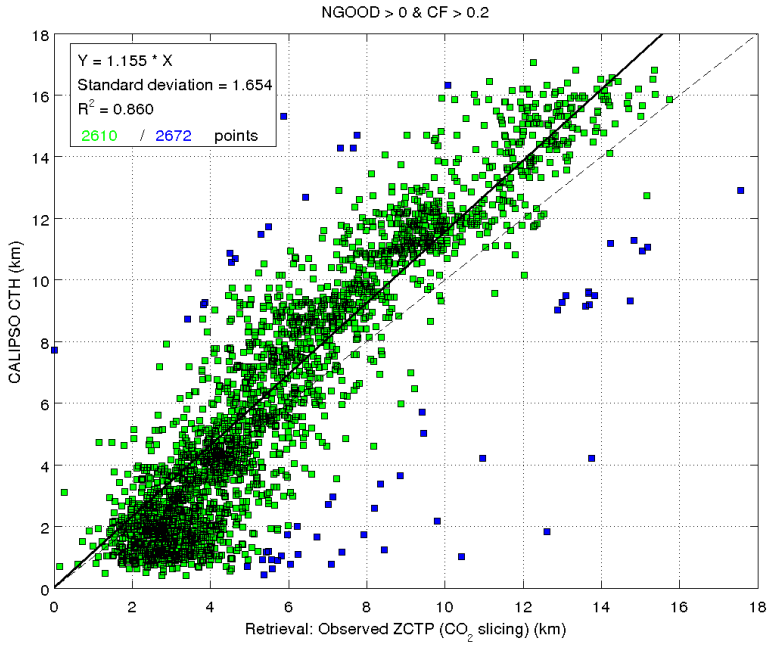




Model output height vs retrieved from simulated AIRS (left)
CALIPSO height vs retrieved from real AIRS (right)
July 15, 2008

-90° ≤ Latitude ≤ +90°

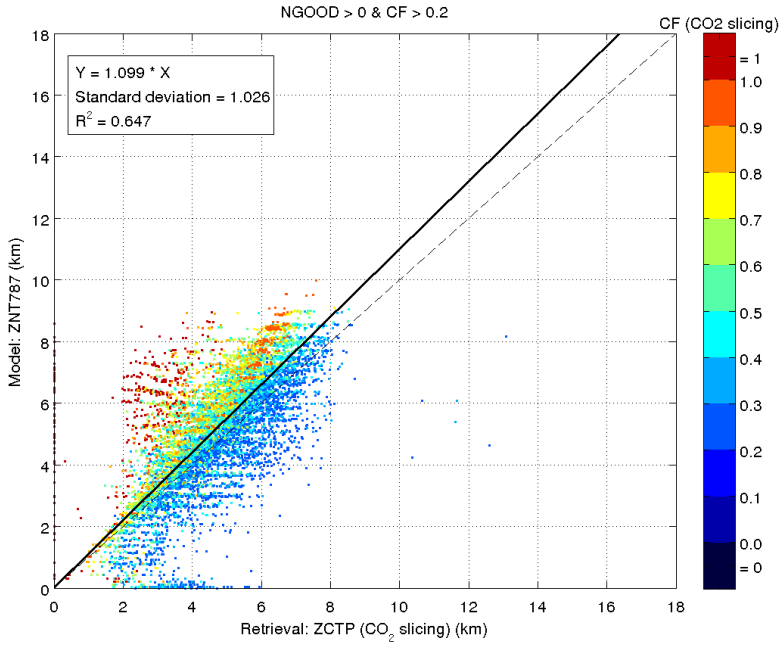


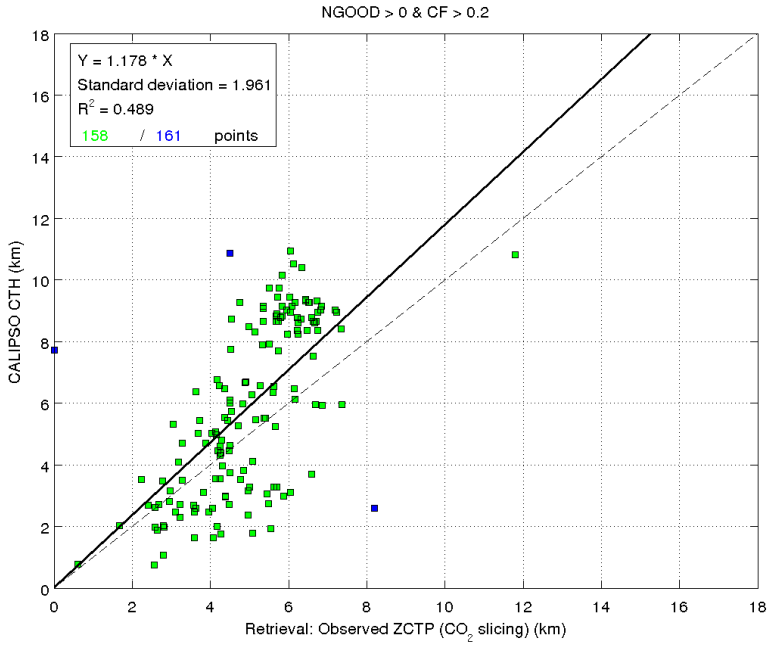


Remarkable similitude in dynamic range and bias attributed to CO2 slicing technique. Implies definition of model height OK.

Model output height vs retrieved from simulated AIRS (left)
CALIPSO height vs retrieved from real AIRS (right)
July 15, 2008

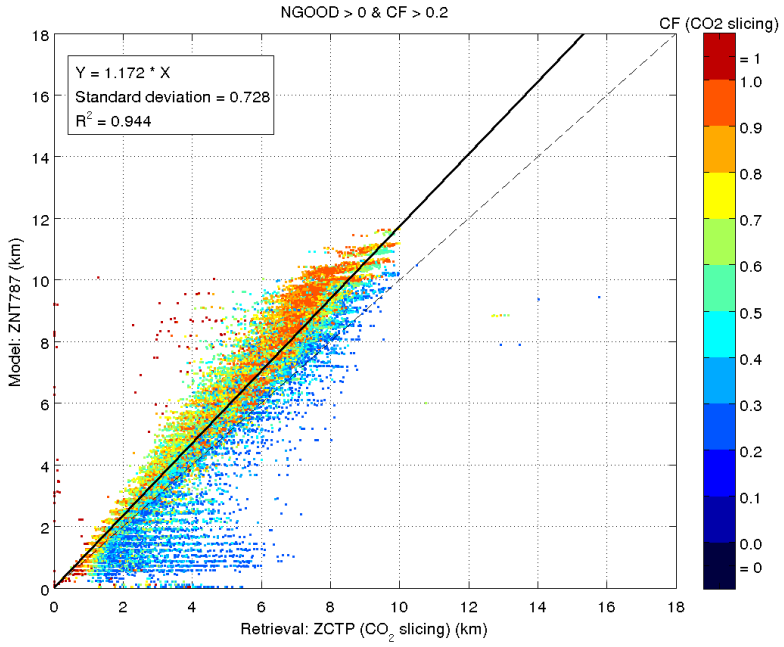
-90° ≤ Latitude < -65°

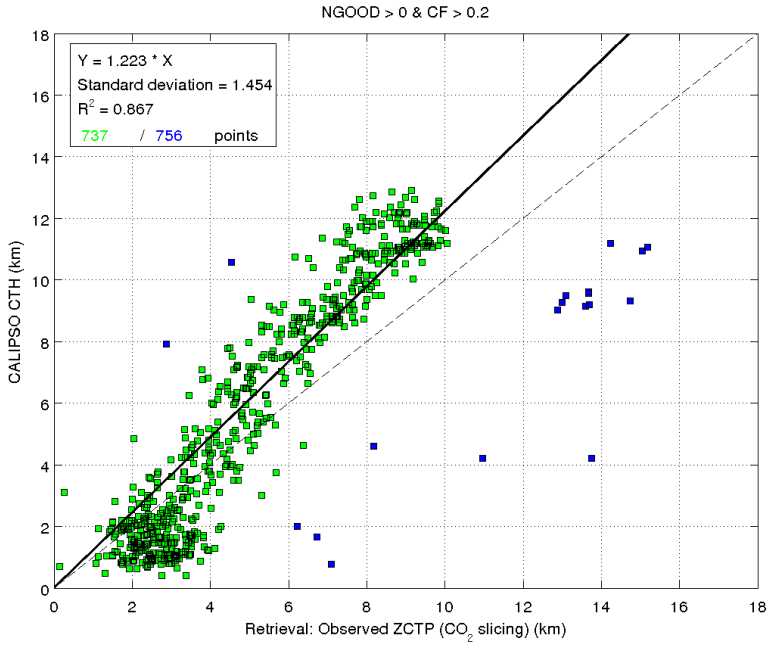




Model output height vs retrieved from simulated AIRS (left)
CALIPSO height vs retrieved from real AIRS (right)
July 15, 2008

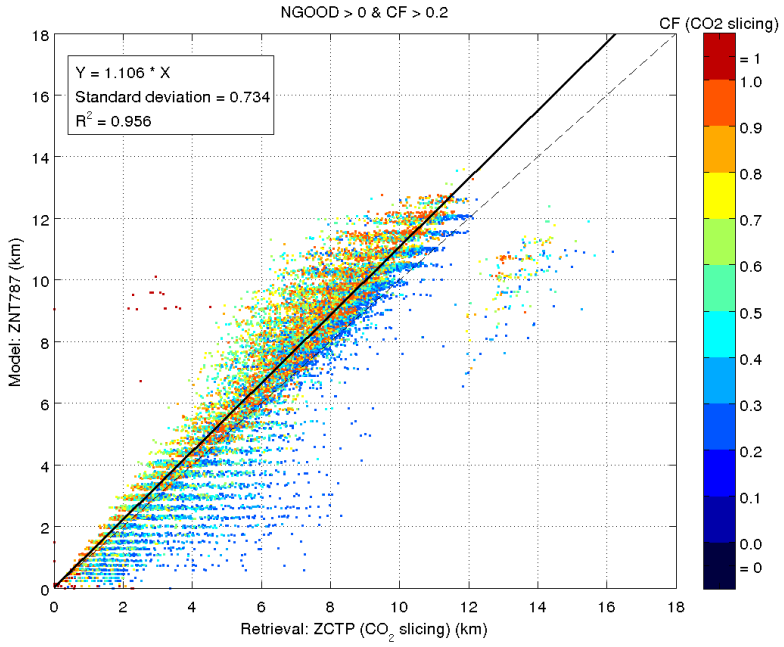
-65° ≤ Latitude < -40°

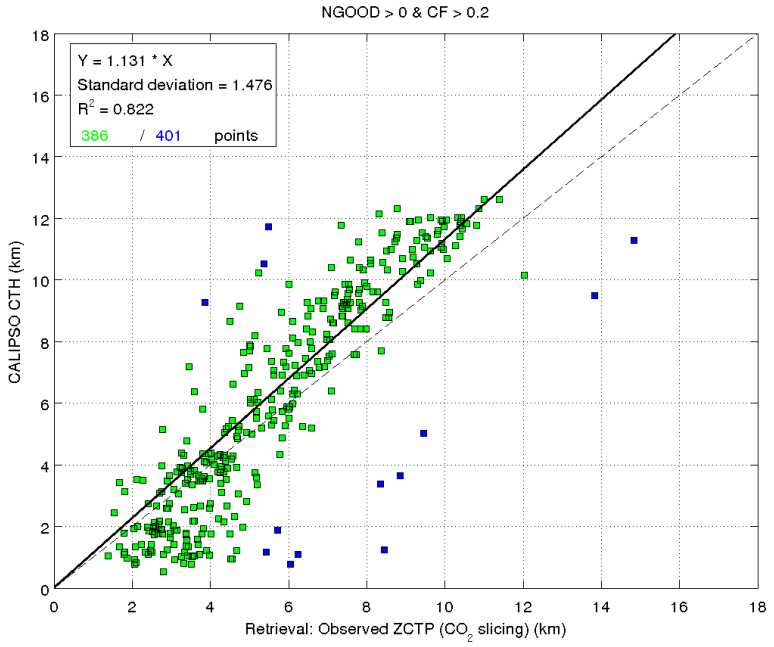




Model output height vs retrieved from simulated AIRS (left)
CALIPSO height vs retrieved from real AIRS (right)
July 15, 2008

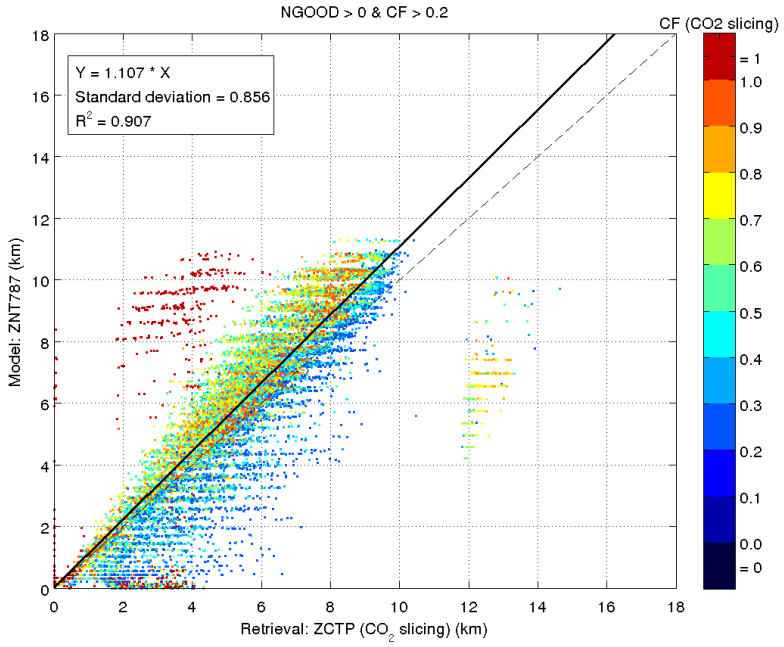
+40° ≤ Latitude < +65°

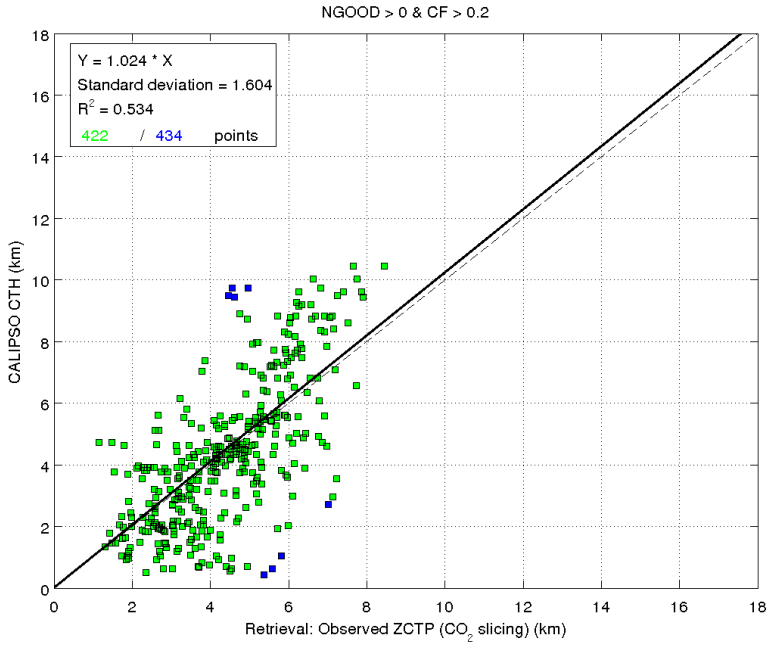




Model output height vs retrieved from simulated AIRS (left)
CALIPSO height vs retrieved from real AIRS (right)
July 15, 2008

+65° ≤ Latitude ≤ +90°

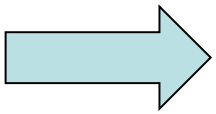




Model validation

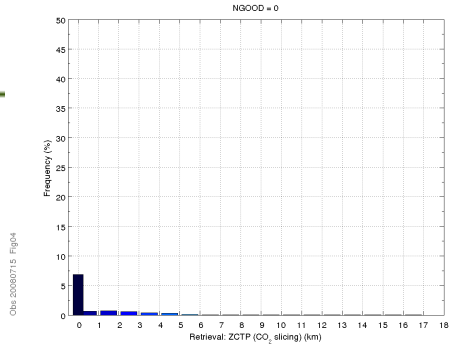
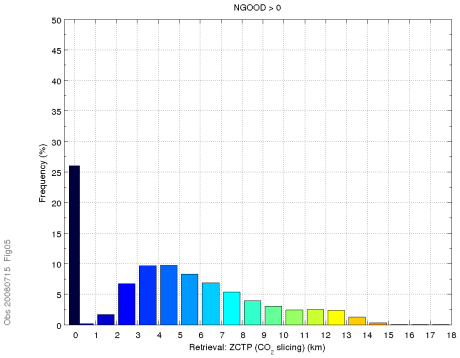
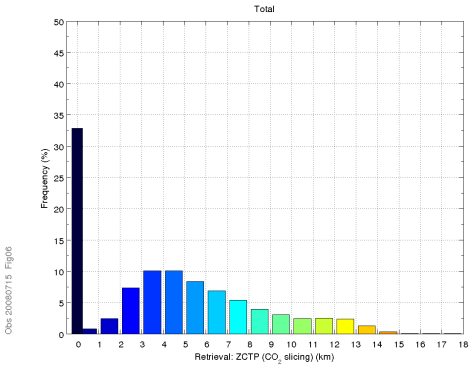
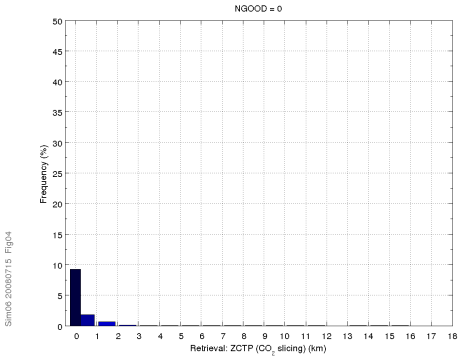
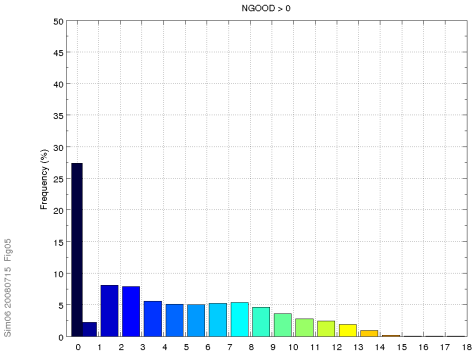
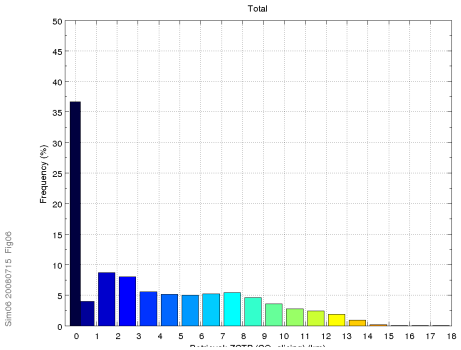
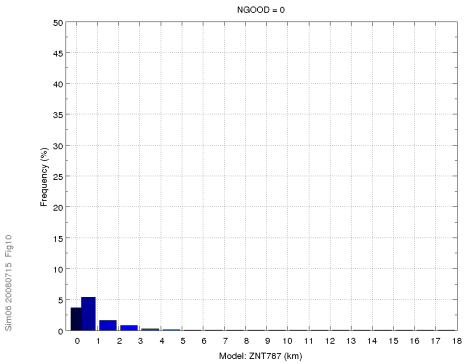
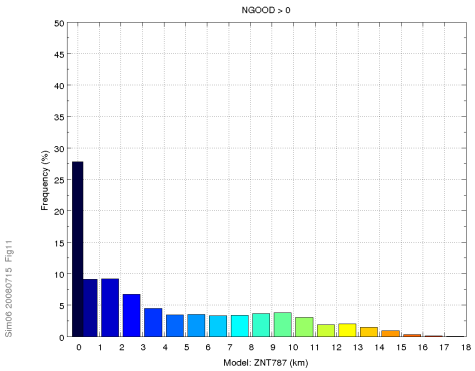
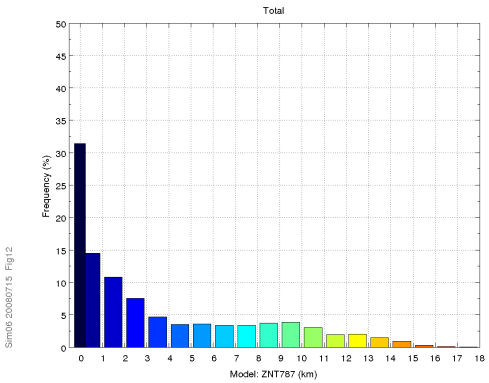
- Comparing height distributions from CO2-slicing applied to both real and simulated data superior to comparing model output height to retrieved height: cancellation of biases induced by retrieval technique.

Note: when Co2-slicing fails (~10 % of cases) the effective height is used by matching window temperature to guess temperature profile, assuming overcast.

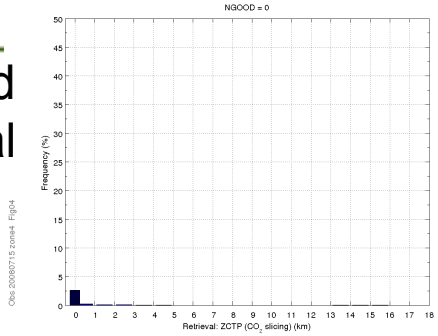
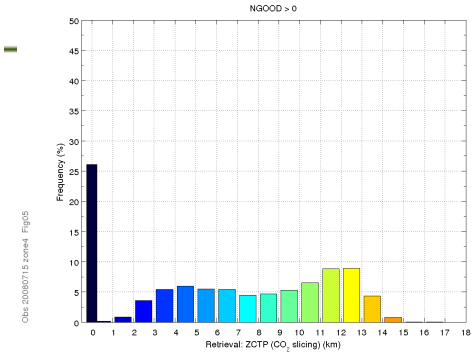
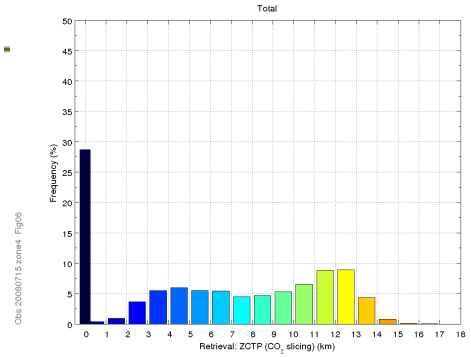
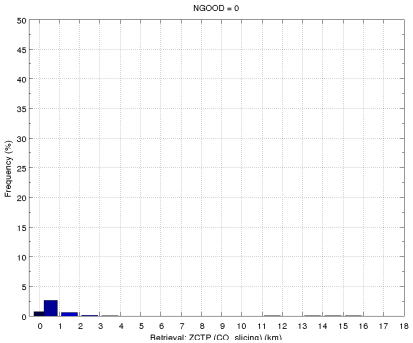
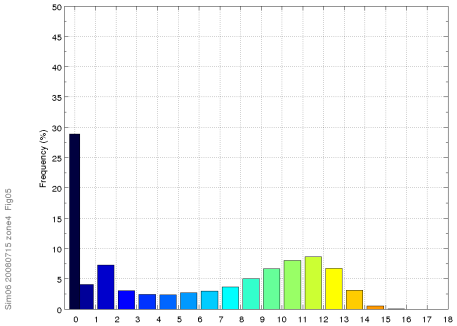
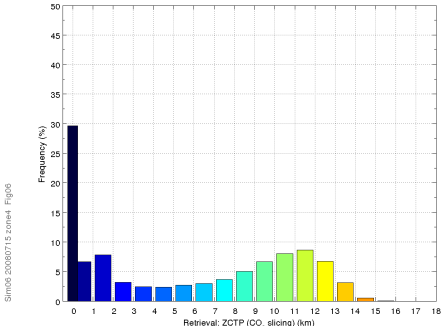
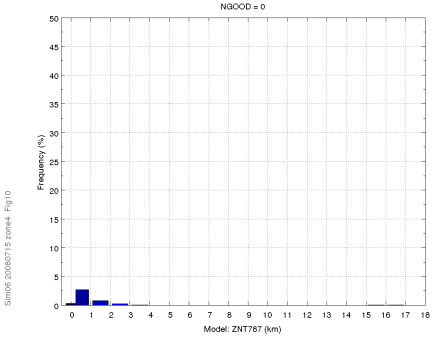
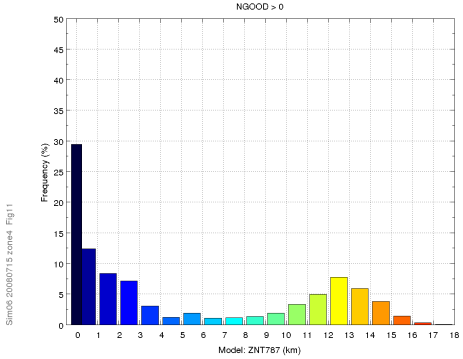
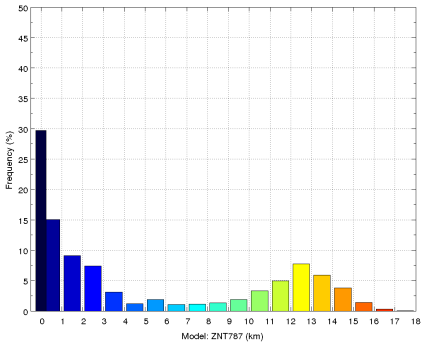


Goal: provide meaningful information to modeler on cloud Parameters and a tool for evaluation

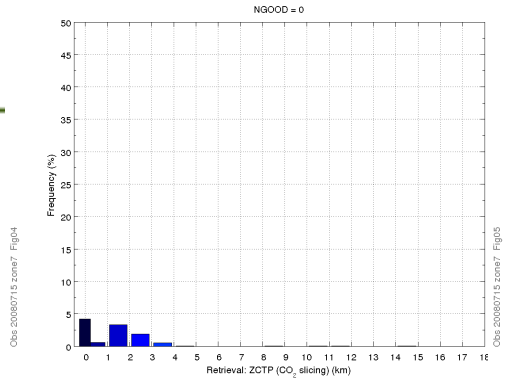
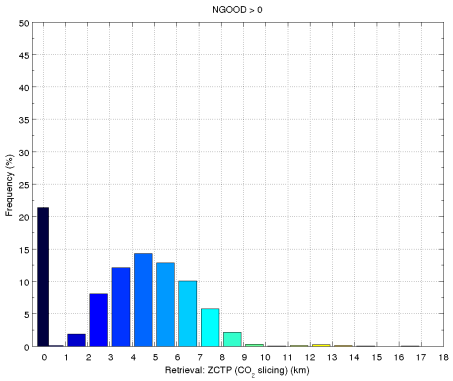
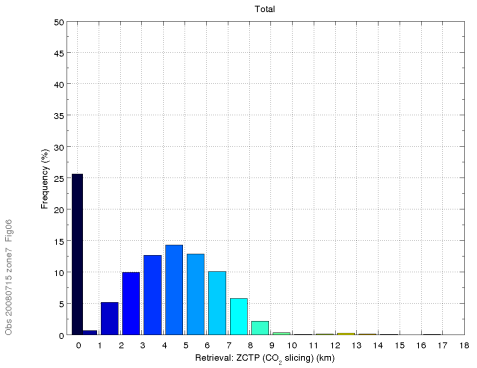
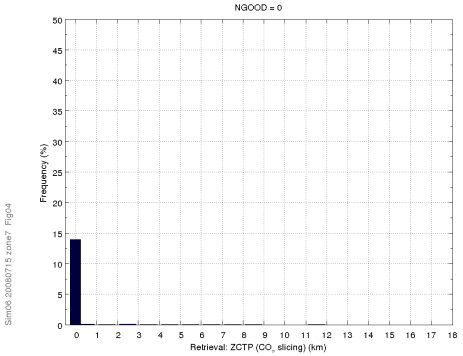
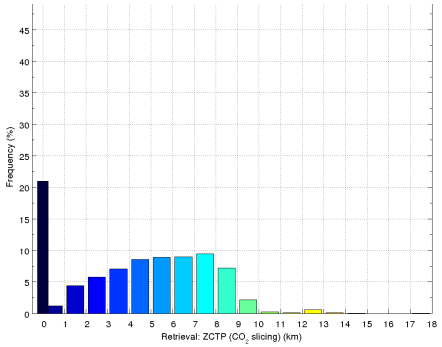
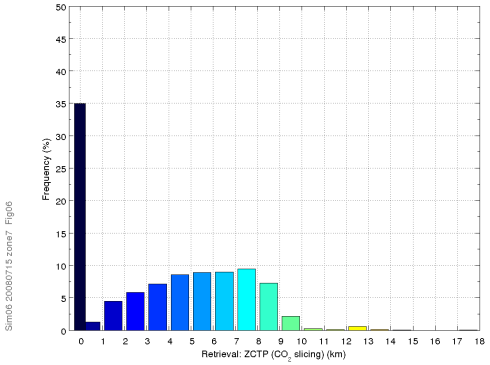
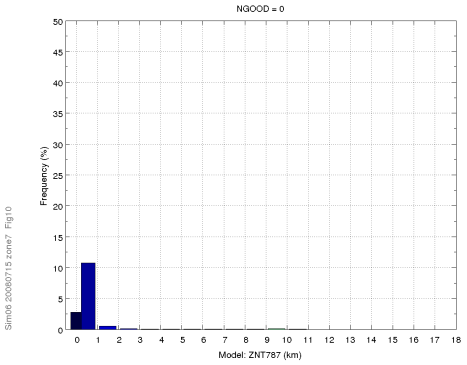
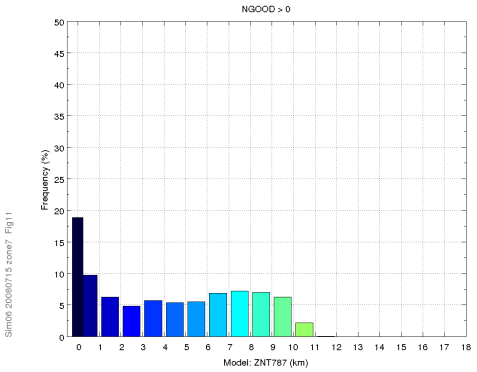
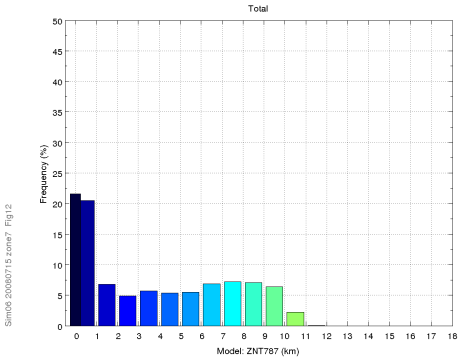
Cloud height distributions leading to model validation, here global data

	Co2-slicing fails	Co2-slicing OK	Total
Retrieved From real Data			
Retrieved From Simulated Data			
Directly from model output			

Validation in Tropics (15S-15N) indicating lack of mid level clouds 3-8 km in model.

	Co2-slicing fails	Co2-slicing OK	Total
Retrieved From real Data			
Retrieved From Simulated Data			
Directly from model output			

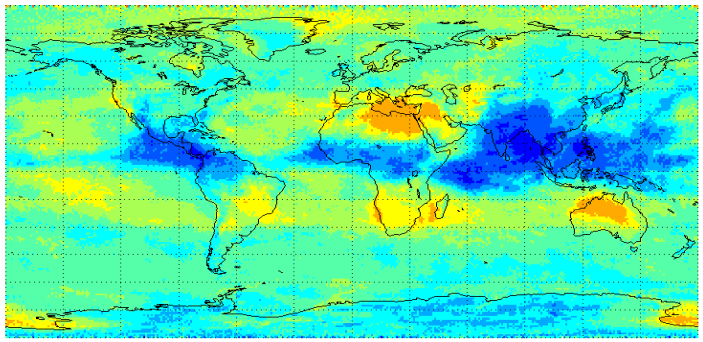
Validation in Arctic, 65-90 N, model distribution is too flat

	Co2-slicing fails	Co2-slicing OK	Total
Retrieved From real Data			
Retrieved From Simulated Data			
Directly from model output			

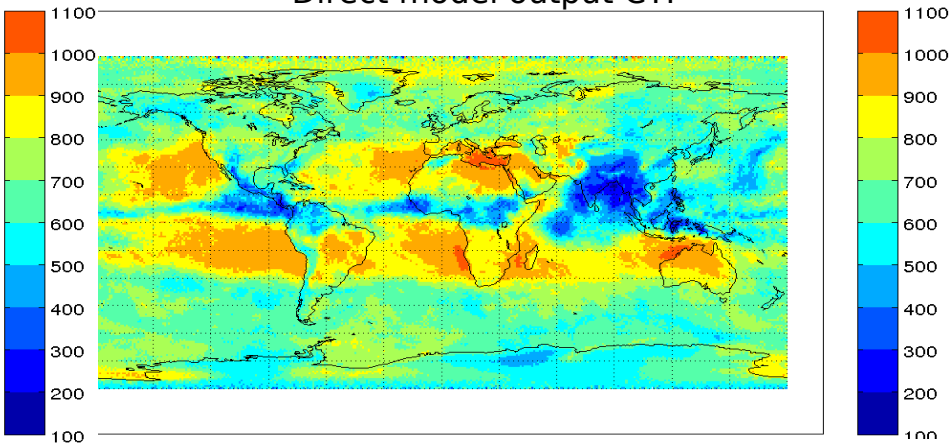
Validation results: monthly maps of cloud parameters.

Cloud Top Pressure (July 2008)

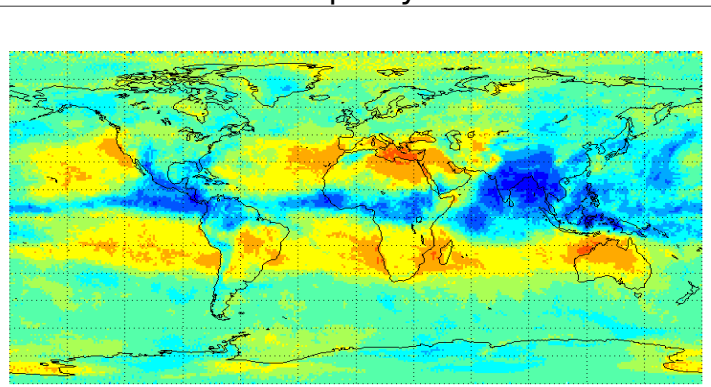
Observed CTP (CO2-slicing)



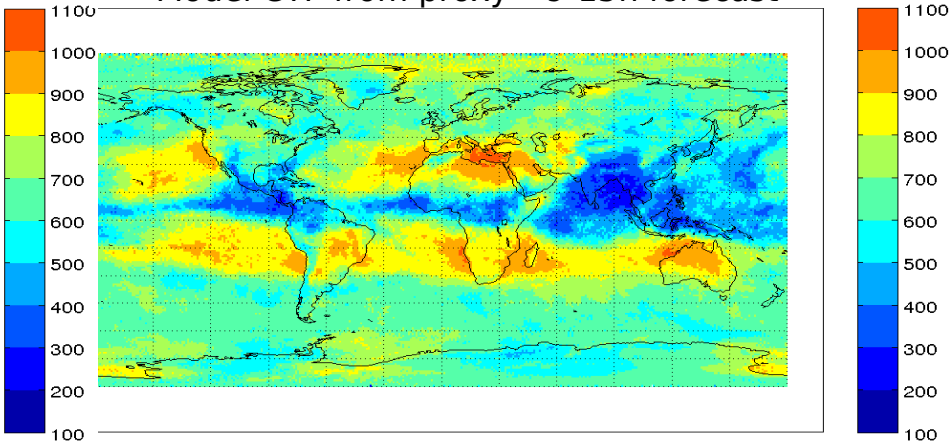
Direct model output CTP



Model CTP from proxy – 3-9h forecast



Model CTP from proxy – 9-15h forecast

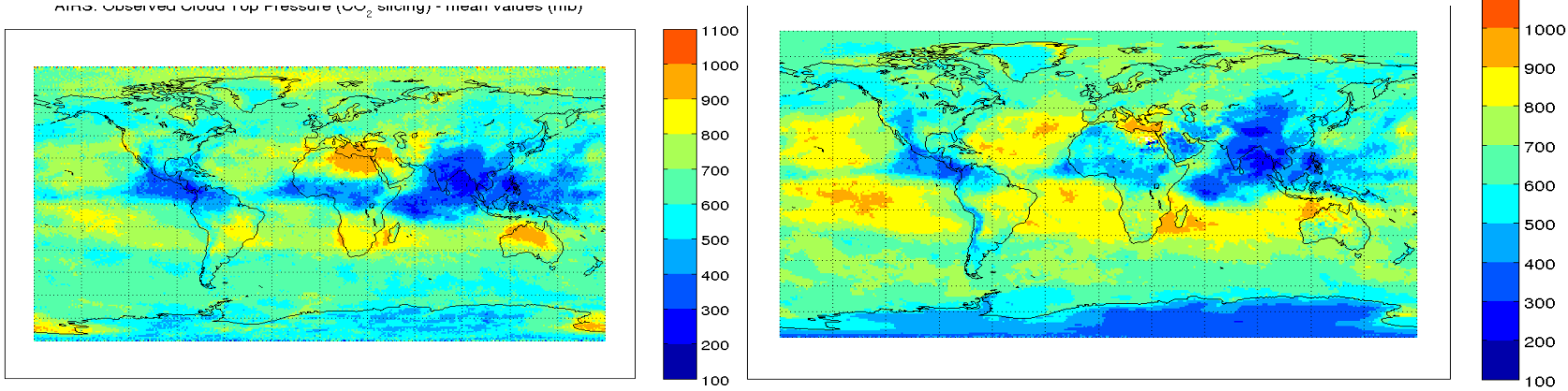


Cloud parameters comparison with MODIS

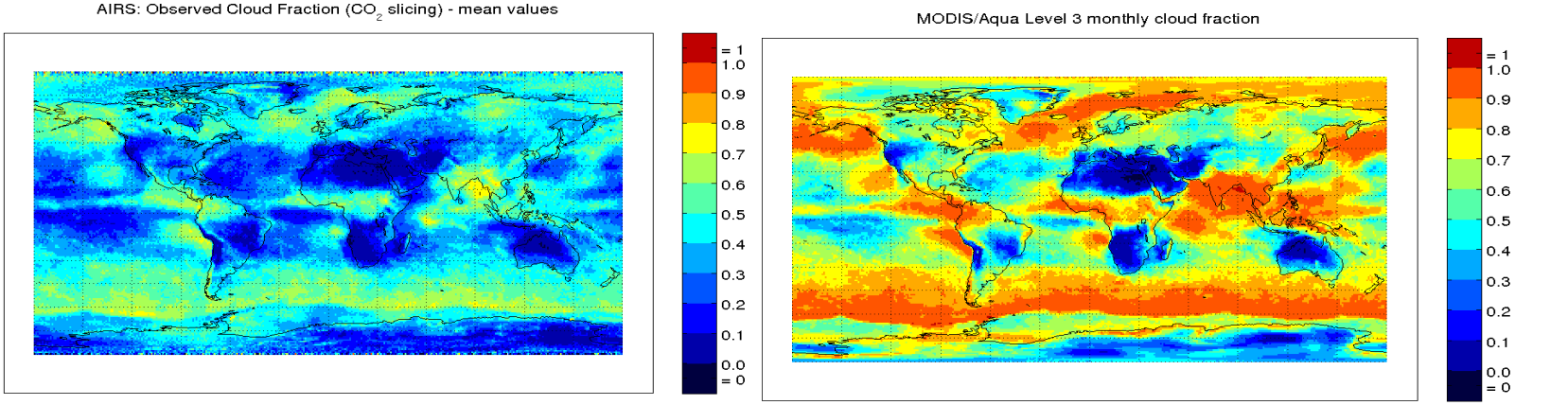
AIRS (retrieval from observations)

MODIS

Cloud Top Pressure



Cloud Fraction

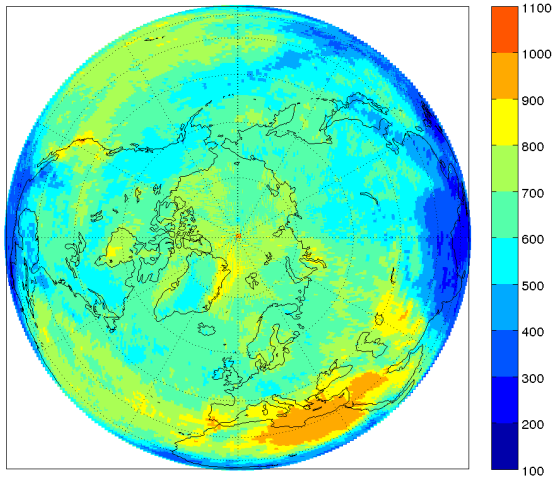


Source: MODIS science team

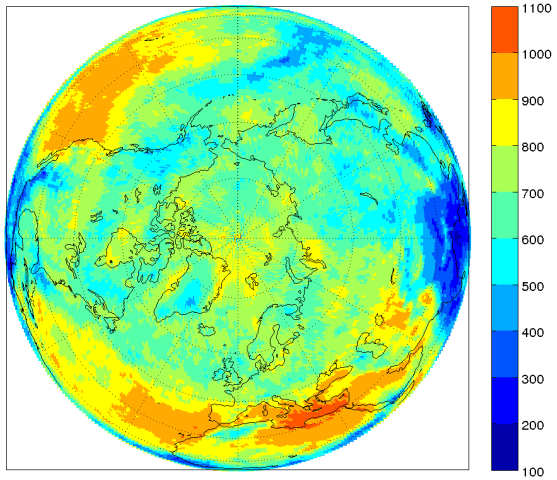
Focus on Arctic area:

Cloud Top Pressure (July 2008)

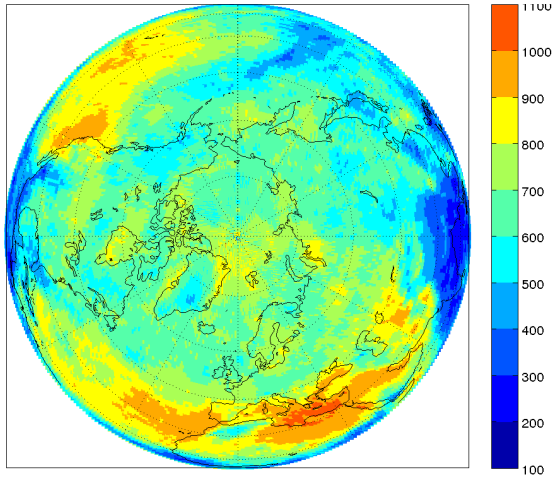
Observed CTP



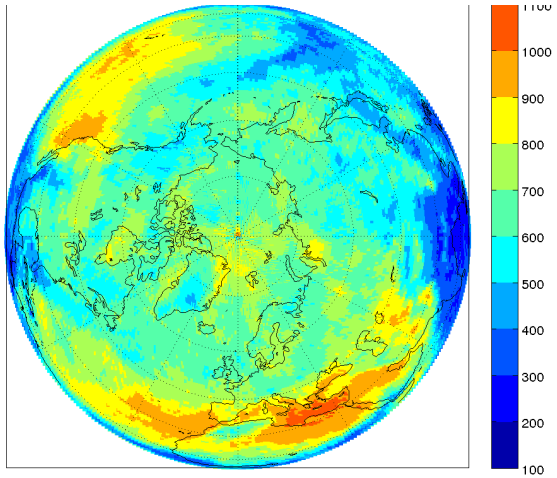
Direct model output CTP



Calculated CTP – 3-9h forecast



Calculated CTP – 9-15h forecast

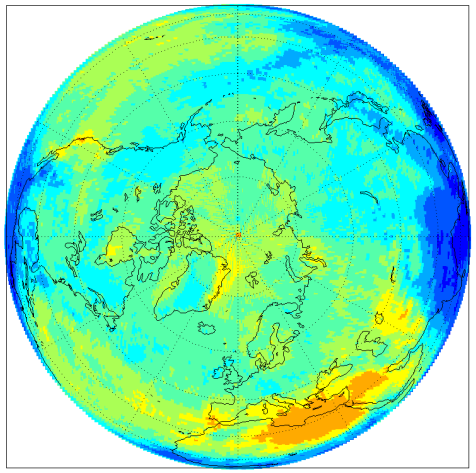


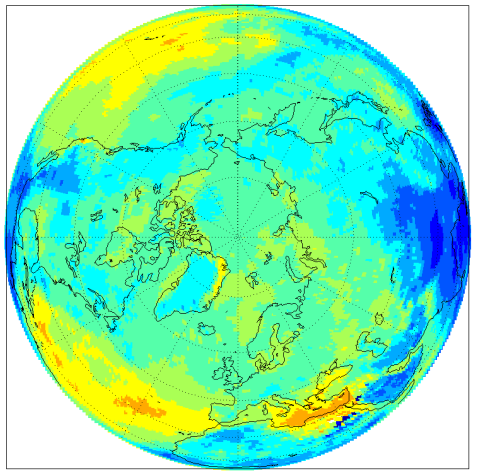
Focus on Arctic area: comparison with MODIS

AIRS (retrieval from observations)

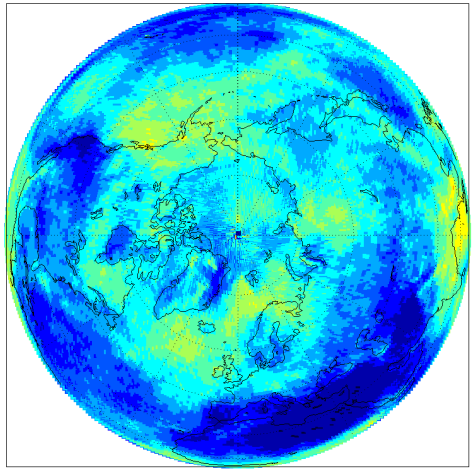
MODIS

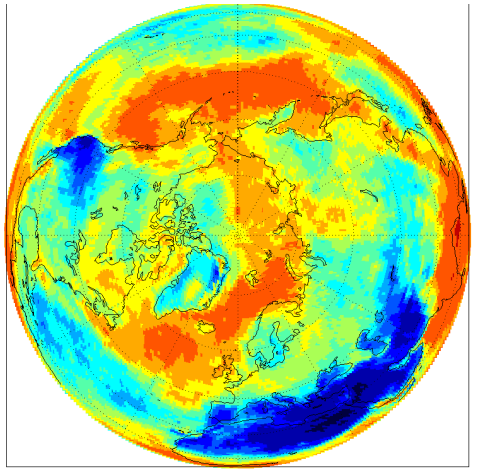
Cloud Top Pressure





Cloud Fraction





Source: MODIS science team

Conclusion

- Co2-slicing revision confirms it is best to limit range to 13.1-14.2 μm, use independent pairs and retain median. This Impacts on radiance quality control.
- Proposed model definition of cloud top corresponds to physical height inferred from lidar Calipso data.
- Height bias increases with height to reach ~2 km at 16 km. This can be accounted for.
- Model validation tool developed based on CO2-slicing applied to both real and proxy data provides useful information on model vertical cloud distribution deficiencies.
- Monthly height distributions from AIRS compare well with MODIS, but amount distributions differ due to nature of retrieval (0-1 values for MODIS, lack of overcast cases for Co2-slicing).